Name:____________________________ Class:__________________ Date:__________________

Sample Problem Set I Solutions

Forces and the Laws of Motion

ADDITIONAL PRACTICE B

Givens	*Solutions*
1. $m_w = 75$ kg $m_p = 275$ kg $g = 9.81$ m/s^2	The normal force exerted by the platform on the weight lifter's feet is equal to and opposite of the combined weight of the weightlifter and the pumpkin. $F_{net} = F_n - m_w g - m_p g = 0$ $F_n = (m_w + m_p)g = (75 \text{ kg} + 275 \text{ kg})\,(9.81 \text{ m/s}^2)$ $F_n = (3.50 \times 10^2 \text{ kg})(9.81 \text{ m/s}^2) = 3.43 \times 10^3 \text{ N}$ $\mathbf{F_n} = \boxed{3.43 \times 10^3 \text{ N upward against feet}}$
2. $m_b = 253$ kg $m_w = 133$ kg $g = 9.81$ m/s^2	$F_{net} = F_{n,1} + F_{n,2} - m_b g - m_w g = 0$ The weight of the weightlifter and barbell is distributed equally on both feet, so the normal force on the first foot ($F_{n,1}$) equals the normal force on the second foot ($F_{n,2}$). $2F_{n,1} = (m_b + m_w)g = 2F_{n,2}$ $F_{n,1} = F_{n,2} = \dfrac{(m_b + m_b)g}{2} = \dfrac{(253 \text{ kg} + 33 \text{ kg})\left(9.81 \dfrac{\text{m}}{\text{s}^2}\right)}{2}$ $F_{n,1} = F_{n,2} = \dfrac{(386 \text{ kg})(9.81 \text{ m/s}^2)}{2} = 1.89 \times 10^3 \text{ N}$ $\mathbf{F_{n,1}} = \mathbf{F_{n,2}} = \boxed{1.89 \times 10^3 \text{ N upward on each foot}}$
3. $F_{down} = 1.70$ N $F_{net} = 4.90$ N	${F_{net}}^2 = {F_{forward}}^2 + {F_{down}}^2$ $F_{forward} = \sqrt{{F_{net}}^2 - {\text{F}_{\text{down}}}^2} = \sqrt{(4.90 \text{ N})^2 - (1.70 \text{ N})^2}$ $F_{forward} = \sqrt{21.1 \text{ N}^2} = \boxed{4.59 \text{ N}}$
4. $m = 3.10 \times 10^2$ kg $g = 9.81$ m/s^2 $\theta_1 = 30.0°$ $\theta_2 = -30.0°$	$F_{x,net} = \Sigma F_x = F_{T,1}(\sin\theta_1) + F_{T,2}(\sin\theta_2) = 0$ $F_{y,net} = \Sigma F_y = F_{T,1}(\cos\theta_1) + F_{T,2}(\cos\theta_2) + \text{Fg} = 0$ $F_{T,1}(\sin 30.0°) = -F_{T,2}[\sin(-30.0°)]$ $F_{T,1} = F_{T,2}$ $F_{T,1}(\cos\theta_1) + F_{T,1}(\cos\theta_2) = -F_g = mg$ $F_{T,1}(\cos 30.0°) + F_{T,1}[\cos(-30.0°)] = (3.10 \times 10^2 \text{ kg})(9.81 \text{ m/s}^2)$ $F_{T,1} = \dfrac{(3.10 \times 10^2 \text{ kg})(9.81 \text{ m/s}^2)}{(2)(\cos 30.0°)[\cos(-30.0°)]}$ $F_{T,1} = F_{T,2} = \boxed{1.76 \times 10^3 \text{ N}}$ As the angles θ_1 and θ_2 become larger, $\cos\theta_1$ and $\cos\theta_2$ become smaller. Therefore, $F_{T,1}$ and $F_{T,2}$ must become larger in magnitude.

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5. $m = 155$ kg

$F_{T,1} = 2F_{T,2}$

$g = 9.81\ \text{m/s}^2$

$\theta_1 = 90° - \theta_2$

Solutions

$F_{x,net} = F_{T,1}(\cos\theta_1) - F_{T,2}(\cos\theta_2) = 0$

$F_{y,net} = F_{T,1}(\sin\theta_1) + F_{T,2}(\sin\theta_2) - mg = 0$

$F_{T,1}[(\cos\theta_1) - \frac{1}{2}(\cos\theta_2)] = 0$

$2(\cos\theta_1) = \cos\theta_2 = \cos(90° - \theta_1) = \sin\theta_1$

$2 = \tan\theta_1$

$\theta_1 = \tan^{-1}(2) = 63°$

$\theta_2 = 90° - 63° = 27°$

$F_{T,1}(\sin\theta_1) + \frac{F_{T,1}}{2}(\sin\theta_2) = mg$

$$F_{T,1} = \frac{mg}{(\sin\theta_1) + \frac{1}{2}(\sin\theta_2)}$$

$$F_{T,1} = \frac{(155\ \text{kg})(9.81\ \text{m/s}^2)}{(\sin 63°) + \frac{(\sin 27°)}{2}} = \frac{(155\ \text{kg})(9.81\ \text{m/s}^2)}{0.89 + 0.23} = \frac{(155\ \text{kg})(9.81\ \text{m})}{1.12}$$

$F_{T,1} = \boxed{1.36 \times 1.36 \times 10^3\ \text{N}}$

$F_{T,2} = \boxed{6.80 \times 10^2\ \text{N}}$

Forces and the Laws of Motion

Problem B

DETERMINING NET FORCE

PROBLEM

The muscle responsible for closing the mouth is the strongest muscle in the human body. It can exert a force greater than that exerted by a man lifting a mass of 400 kg. Richard Hoffman of Florida recorded the force of biting at 4.33×10^3 N. If each force shown in the diagram below has a magnitude equal to the force of Hoffman's bite, determine the net force.

SOLUTION

1. **DEFINE** **Define the problem, and identify the variables.**

Given:

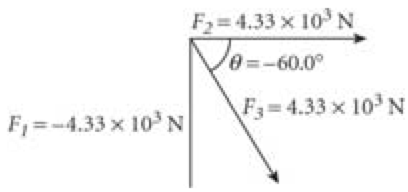
$F_1 = -4.33 \times 10^3$ N

$F_2 = 4.33 \times 10^3$ N

$F_3 = 4.33 \times 10^3$ N

Unknown: $F_{net} = ?$ $\theta_{net} = ?$

Diagram:



2. **PLAN** **Select a coordinate system, and apply it to the free-body diagram:** Let F_1 lie along the negative y-axis and F_2 lie along the positive x-axis. Now F_3 must be resolved into x and y components.

3. **CALCULATE** **Find the *x* and *y* components of all vectors:** As indicated in the sketch, the angle between F_3 and the x-axis is 60.0°. Because this angle is in the quadrant bounded by the positive x and negative y axes, it has a negative value.

$F_{3,x} = F_3(\cos\theta) = (4.33 \times 10^3 \text{ N})[\cos(-60.0°)] = 2.16 \times 10^3 \text{ N}$

$F_{3,y} = F_3(\sin\theta) = (4.33 \times 10^3 \text{ N})[\sin(-60.0°)] = -3.75 \times 10^3 \text{ N}$

Find the net external force in both the *x* and *y* directions.

For the x direction: $\Sigma F_x = F_2 + F_{3,x} = F_{x,net}$

$\Sigma F_x = 4.33 \times 10^3 \text{ N} + 2.16 \times 10^3 \text{ N} = 6.49 \times 10^3 \text{ N}$

For the y direction: $\Sigma F_y = F_1 + F_{3,y} = F_{y,net}$

$\Sigma F_y = (-4.33 \times 10^3 \text{ N}) + (-3.75 \times 10^3 \text{ N}) = -8.08 \times 10^3 \text{ N}$

Find the net external force.

Use the Pythagorean theorem to calculate F_{net}. Use $\theta_{net} = \tan^{-1}\left(\frac{F_{y,net}}{F_{x,net}}\right)$ to find the angle between the net force and the x-axis.

$$F_{net} = \sqrt{(F_{x,net})^2 + (F_{y,net})}$$

$$F_{net} = \sqrt{(6.49 \times 10^3 \text{N})^2 + (-8.08 \times 10^3 \text{N})^2} = \sqrt{10.74 \times 10^7 \text{N}^2}$$

$$F_{net} = 1.036 \times 10^4 \text{N}$$

$$\theta_{net} = \tan^{-1}\left(\frac{-8.08\times10^{3}\,\text{N}}{6.49\times10^{3}\,\text{N}}\right) = -51.2°$$

4. **EVALUATE** The net force is larger than the individual forces, but it is not quite three times as large as any one force, which would be the case if all three forces were acting in one direction only. The angle is negative to indicate that it is in the quadrant below the positive x-axis, where the values along the y-axis are negative. The net force is 1.036×10^4 N at an angle of 51.2° below the positive x-axis.

ADDITIONAL PRACTICE

1. Joe Ponder, from North Carolina, once used his teeth to lift a pumpkin with a mass of 275 kg. Suppose Ponder has a mass of 75 kg, and he stands with each foot on a platform and lifts the pumpkin with an attached rope. If he holds the pumpkin above the ground between the platforms, what is the force exerted on his feet? (Draw a free-body diagram showing all of the forces present on Ponder.)
2. In 1994, Vladimir Kurlovich, from Belarus, set the record as the world's strongest weightlifter. He did this by lifting and holding above his head a barbell whose mass was 253 kg. Kurlovich's mass at the time was roughly 133 kg. Draw a free-body diagram showing the various forces in the problem. Calculate the normal force exerted on *each* of Kurlovich's feet during the time he was holding the barbell.
3. The net force exerted by a woodpecker's head when its beak strikes a tree can be as large as 4.90 N, assuming that the bird's head has a mass of 50.0 g. Assume that two different muscles pull the woodpecker's head forward and downward, exerting a net force of 4.90 N. If the forces exerted by the muscles are at right angles to each other and the muscle that pulls the woodpecker's head downward exerts a force of 1.70 N, what is the magnitude of the force exerted by the other muscle? Draw a free-body diagram showing the forces acting on the woodpecker's head.
4. About 50 years ago, the San Diego Zoo, in California, had the largest gorilla on Earth: its mass was about 3.10×10^2 kg. Suppose a gorilla with this mass hangs from two vines, each of which makes an angle of 30.0° with the vertical. Draw a free-body diagram showing the various forces, and find the magnitude of the force of tension in each vine. What would happen to the tensions if the upper ends of the vines were farther apart?
5. The mass of Zorba, a mastiff born in London, England, was measured in 1989 to be 155 kg. This mass is roughly the equivalent of the combined masses of two average adult male mastiffs. Suppose Zorba is placed in a harness that is suspended from the ceiling by two cables that are at right angles to each other. If the tension in one cable is twice as large as the tension in the other cable, what are the magnitudes of the two tensions? Assume the mass of the cables and harness to be negligible. Before doing the calculations, draw a free-body diagram showing the forces acting on Zorba.